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Grip Strength as an Indicator of Occupational Health In BMP II Combat Vehicle: Correlation With Body Mass Index

Deepika Kakkar [1], Shweta Rawat [1], Inderjeet Singh [1], Yashmita Chaudhary [1], Lalhmunlien Robert Varte [1, *]

[1] Human Biology Group, Defence Institute of Physiology and Allied Sciences, Defence Research & Development Organization(DRDO), Ministry of Defence, Govt. of India, Lucknow Road, Timarpur, Delhi-110054, India

* Corresponding author email: robvarte.dipas@gov.in

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Abstract

Introduction: Hand grip strength (HGS) is a longstanding surrogate of muscular strength and functional capacity which in the military is especially important to the populations due to their physical Readiness. This is because Body Mass Index (BMI) which is one of the most common measures to aid in determining the parameters of body composition is subjected to limitations when used in case of physically trained people like the soldiers, who do not have much fat mass in their body. The research is conducted to find out the services of hand grip strength to BMI amongst Indian soldiers serving in the BMP II combat vehicle. **Methods:** 200 male study participants within the age group of 21-50 years old were studied using cross-sectional study at the Indian Army stations. The calculation of BMI and classification into Adolphe and Asia-Pacific was done by the use of standard formulas. Hand grip strength was measured using a digital dynamometer. Body composition parameters were measured by an analysis performed through bioelectrical impedance analysis (BIA). The statistical analysis (Pearson correlation analysis and graphic presentation using boxplot) has been made by using SPSS v20. **Results:** The BMI classification displayed that 57.4 percent of members were of the normal weight group whereas 40.5 percent of the members were overweight. Using correlation, it was noted that BMI had little to do with the hand grip strength ($r = 0.231$ (overweight category), whereas FFM and TBW indicated a significant relationship ($r>0.53$) with both right and left hand grip strength. Boxplot was also used to visualize the overlap in functions between BMI categories whereby some of the overweight individuals showed more grip strength as compared to those who were normal- weight. **Conclusion:** BMI itself is not a proper measurement of functional strength among trained soldiers. Muscular strength can better be predicted by Fat-Free Mass and Total Body Water. These results indicate the necessity to integrate both functional and composition-based testing as part of the military health and fitness guidelines, which no longer adhere to the BMI-specific approach.

Keywords: Body Mass Index (BMI), Hand Grip Strength, Fat-Free Mass, Military Fitness, Physical Performance, Bioelectrical Impedance Analysis

Fuerza de agarre como indicador de salud ocupacional en el vehículo de combate BMP II: correlación con el índice de masa corporal

Resumen

Introducción: La fuerza de prensión manual (HGS) es un indicador tradicional de la fuerza muscular y la capacidad funcional, especialmente importante en el ámbito militar debido a su preparación física. Esto se debe a que el índice de masa corporal (IMC), una de las medidas más comunes para determinar la composición corporal, presenta limitaciones en personas con entrenamiento físico, como los soldados, quienes presentan baja masa grasa corporal. Esta investigación busca determinar la relación entre la fuerza de prensión manual y el IMC entre soldados indios que prestan servicio en el vehículo de combate BMP II. **Métodos:** Se estudió a 200 participantes varones de entre 21 y 50 años mediante un estudio transversal en las bases del Ejército indio. El cálculo del IMC y

la clasificación en las regiones Adolphe y Asia-Pacífico se realizó mediante fórmulas estándar. La fuerza de prensión manual se midió con un dinamómetro digital. Los parámetros de composición corporal se midieron mediante análisis de impedancia bioeléctrica (BIA). El análisis estadístico (análisis de correlación de Pearson y presentación gráfica mediante diagrama de caja) se realizó mediante SPSS v20. **Resultados:** La clasificación del IMC mostró que el 57.4 por ciento de los miembros pertenecían al grupo de peso normal, mientras que el 40,5 por ciento de los miembros tenían sobrepeso. Mediante la correlación, se observó que el IMC tenía poca relación con la fuerza de prensión manual (r = 0,231 [categoría de sobrepeso]), mientras que la masa muscular libre de grasa (MLG) y el peso corporal total (ACT) indicaron una relación significativa (r > 0,53) con la fuerza de prensión manual, tanto derecha como izquierda. También se utilizó un diagrama de caja para visualizar la superposición de funciones entre las categorías de IMC, donde algunos individuos con sobrepeso mostraron mayor fuerza de prensión que aquellos con peso normal. **Conclusión:** El IMC por sí solo no es una medida adecuada de la fuerza funcional en soldados entrenados. La fuerza muscular se puede predecir mejor mediante la masa libre de grasa y el agua corporal total (AQT). Estos resultados indican la necesidad de integrar pruebas funcionales y basadas en la composición muscular como parte de las directrices militares de salud y acondicionamiento físico, que ya no se adhieren al enfoque específico del IMC.

Palabras Clave: Índice de Masa Corporal (IMC), Fuerza de Prensión Manual, Masa Libre de Grasa, Aptitud Física Militar, Rendimiento Físico, Análisis de Impedancia Bioeléctrica

Introduction

The hand grip strength is gaining popularity in being a valid surrogate measure of overall muscular strength and functional capacity among disparate groups of people. It is a non-invasive, economical means of measuring the health of the musculoskeletal system and has been linked to not only the nutritional status but also the physical performance, morbidity, and even mortality in some cases (Leong *et al.,* 2015). Hand grip strength is therefore a good indicator of combat preparedness especially in the mechanized infantry and armored personnel such as the BMP II combat vehicles operators where the physical inventory such as endurance and strength directly pertains to the effectiveness of operations and completion of missions.

Body Mass Index (BMI), is also a most commonly used anthropometric measure for nutritional status for underweight, normal, overweight, or obese categories. Although simple, popular, and heavily used, BMI is not directly related to the volume of muscles, body composition, and the potential to achieve better physical performance (Nuttall, 2015). In Army when BMI is used alone, it can conceal significant factors in fitness and functional strength between personnel whose lean mass can be higher, but still continue to fit into higher BMI categories. The infantry combat vehicles used by Indian army troops is BMP II (Boyevaya Mashina Pekhoty) which frequently expose the soldiers into a physical stress during long periods of immobility which limits the area of operation.

To overcome this problem Army personal needs very strong body, build mostly in the upper limbs. Therefore, it is necessary to identify whether only BMI, can be applied during recruitment and routine health check is enough to identify the abilities of Indian soldiers in their functional strengths or should more parameters like hand grip strength, be included in health assessment.

Thus, the aim and objectives of the present Study were:

i. To categorize BMI of Indian soldiers by using both Adolphe and Asia-Pacific classification of BMI.

ii. To determine the relationship between the BMI and the hand grip strength.

iii. In order to compare the hand grip strength with other body composition parameters such as the TBW and the FFM.

iv. To determine that BMI can be a good predictor of functional strength among active-duty soldiers in the Indian population.

v. to find out whether BMI is a significant predictor of upper limb strength in Indian Army

Materials and Methods

Study Design

The research was a cross sectional observational study in which correlation was investigated between Body Mass Index (BMI) and Hand Grip strength in the Indian soldiers, used in BMP II combat vehicles. The design made it possible to measure anthropometric and strength parameters simultaneously in order to determine the tendencies of association between them without any experimentation leads or making an intervention.

Study Population

200 male Indian male soldiers aged 21 to 50 years selected among Indian Army units which have been trained and given a task on BMP II combat vehicles. A convenient sampling method was used to select the participants and they all were actively serving individuals with no documented upper limb musculoskeletal injury and chronic diseases that could affect their strength or anthropometric assessment. The mention of nothing more than the mechanized infantry personnel makes it relevant to the operational needs and physical needs of the deployment of BMP II combat vehicles.

Ethical Considerations: The research was carried out by ethical principles stipulated in the Declaration of Helsinki. Verbal and written informed consent was taken before the data was collected.

Anthropometric Measurements

Body Weight and Height

Height and Body mass were measured according to the methods standardized by International Society for the Advancement of Kinanthropometry (ISAK) with a Electronic Weighing scale and Stadiometer.

Body Mass Index (BMI)

BMI was calculated using the standard formula:

BMI= weight (kg)/ height (m)^2

The BMI of each of the participants was then divided into two classification standards:

(i) Adolphe Classification (Adolphe et al., 2017)

Normal Weight (NW): BMI 18.5–24.9

Overweight (OW): BMI 25.0–29.9

Obese-I (OB-I): BMI 30.0–34.9

Obese-II (OB-II): BMI ≥ 35.0

(ii) Asia-Pacific Classification (WHO, 2016)

Underweight: <18.5

Normal Weight: 18.5–22.9

Overweight: 23.0–24.9

Obese-I: 25.0–29.9

Obese-II: ≥30.0

Such a bifurcated classification provided an opportunity of considering the differences in BMI classification between Western and South-Asian specific frameworks in a comparatively analyzable way.

Hand Grip Strength Assessment: The strength of the hand grip was measured by using a verified electric hand dynamometer from Takai Japan. The highest value was taken on each side (right and left hands) according to standard protocol (Norman, 2019 ; Azzam, et al., 2020).

Body Composition Analysis: The Tanita Body Composition Analyzer uses bioelectrical impedance analysis (BIA) to assess body composition. Users stand barefoot on metal footplates, allowing a safe electrical

signal to pass through the body. The device measures resistance to calculate fat, muscle mass, water, and more. For accurate results, avoid eating, drinking, or exercising beforehand. The process is fast, non-invasive, and provides detailed health metrics within seconds to support fitness and wellness goals.

Statistical Analysis: IBM SPSS version 20 was used for Statistical Analysis.

Results

Table 1. Descriptive Statistics of Study Variables (n = 200)

Variable	Mean	SD	Min	Max
Age (years)	34.84	6.01	20.00	50.00
BMR (kcal/day)	1684.38	121.74	1367.0	1966.0
Impedance (ohms)	486.09	47.09	364.0	597.0
Fat %	18.12	4.33	5.80	33.10
Fat Mass (kg)	13.36	4.38	3.60	30.80
Fat-Free Mass (kg)	58.65	4.97	32.00	70.90
Total Body Water (kg)	42.99	3.38	33.80	51.50
RH Grip Strength (kg)	41.63	7.85	17.30	57.30
LH Grip Strength (kg)	40.38	7.64	17.00	56.40
Stature (cm)	171.47	4.52	160.00	184.80

* BMR = Basal Metabolic Rate; RH = Right Hand; LH = Left Hand; FFM = Fat-Free Mass; TBW = Total Body Water.

The sample population (200) was of a middle-service average of 34.84 years (SD 6.01), and the number of field experiences was high. BMR value of 1684.38 kcal/day, a standard deviation of 199.98 kcal/day, a significant coefficient of variation of 12.05, and individual BMR values ranged between 1367 kcal/day and 1966 kcal/day, which is a significant proportion of the range of BMR values that characterize different metabolisms at the population cohort level (Table 1).

The analysis of body composition indicates that soldiers have mean fat percentage of 18.12 (SD = 4.33) with the fat mass between 3.6 kg and 30.8 kg and average of 13.36 kg. On the other hand, the fat free mass (FFM), comprised of muscle, bone and water, mean of 58.65 kg, implying that the participants were well muscularly trained. Total Body Water (TBW) which is a component of FFM was 42.99 kg which is also in line with the standards of hydration in healthy adults males (Table 1).

Notably, the level of hand grip strength, assessed using digital hand dynamometer, was very strong throughout the sample with hand grip strength on the right hand calculated at 41.63 kg and on the left hand 40.38 kg (Table1). Limbs had the least range of difference, which justified the expectations of even upper-body development, as a result of regular exercises and military training. Lastly, the average height was 171.47 cm which was between 160 cm and 184.8 cm, which corroborated a somewhat uniform distribution of the height among the sample.

BMI Classification and Distribution

In the present study, 57. 5 % soldiers were within Normal Weight category whereas 40.5% were classified as Overweight 1.0% were categorized as Underweight and 1.0% were in obese category (Table 2)

This classification data provides a critical foundation for the next phase of the analysis, where the correlation between BMI and hand grip strength will be examined to evaluate the functional validity of BMI as a strength predictor in military populations (Table 3).

Correlation among BMI, body composition and hand grip strength inseminating the correlation between the hand grip strength and the variables associated with BMI, Pearson correlation was determined. The purpose was to find out whether usual anthropometric and physiological variables including Fat Mass, Fat-Free Mass (FFM), and Total Body Water (TBW) agrees with Right Hand Grip Strength (RH Grip) in addition to the Left Hand Grip Strength (LH Grip) significantly (Table 3).

Table 2. BMI Classification of Soldiers Based on Adolphe Criteria

BMI Classification	Frequency	Percentage (%)
Normal Weight (NW)	114	57.5
Overweight (OW)	83	40.5
Underweight (UW)	2	1.0
Obese	2	1.0
Total	**200**	**100.0**

* Note. BMI classifications were based on the Adolphe standard. NW = 18.5–24.9 kg/m², OW = 25–29.9 kg/m², Obese ≥ 30 kg/m², UW < 18.5 kg/m².

Table 3. Pearson Correlation Coefficients between Body Composition and Hand Grip Strength

Variable Pair	Correlation ‘ r ‘
FFM and Right Hand Grip Strength	0.58
FFM and Left Hand Grip Strength	0.56
Total Body Weight and Right Hand Grip Strength	\x0.54
Total Body Weight and Left Hand Grip Strength	0.53
Fat Mass and Right Hand Grip Strength	0.28
Fat Mass and Left Hand Grip Strength	0.26

Key Findings

There was a significant positive relationship between FFM and RH Grip (r = 0.58), as well as LH Grip (r = 0.56), which indicates that the leaner muscle mass that a person has, the stronger he/ she is going to be. TBW likewise displayed moderate to solid constructive affinity with RH Grip (r = 0.54) and LH Grip (Table 3).

(r = 0.53), agreeing with the physiology since water is one of the key compounds of the muscle tissue.

Fat Mass however was weaker at r = 0.28 (RH Grip) and r = 0.26 (LH Grip). This implies that extra fatness cannot add any significant contribution towards the hand grip strength or at least it masks the strength value afforded by BMI (Table 3).

In general, the figures indicate that hand grip strength is more closely associated with functional mass (FFM, TBW) as opposed to total body weight and fat mass.

Results of the present study also support the original idea that BMI is a tool of general population but it is not specific enough to assess the strength potential of population with appropriate training such as soldiers. Hand grip strength is strongly associated with actual measures of the muscular composition, including FFM and TBW, compared to BMI or even fat mass (Table 2).

As it can be seen in Figure 1, the soldiers in Normal Weight (NW) range showed a great variety of the right-hand grip strength results, and some of them showed outliers that were beyond 50 kgs. The Overweight (OW)

group had a slightly elevated median grip strength than the NW group although it was more erratic. Interestingly the Obese and Underweight (UW) groups gave skewed distributions because the sample was very small (n = 2 each) so it cannot be assumed that the distributions are generally true. However, the fact that there were high performers in all the groups indicates that there would be no linear relationship between BMI and grip performance. Similar trend was observed in left hand grip strength of the present study (Figure 3.).

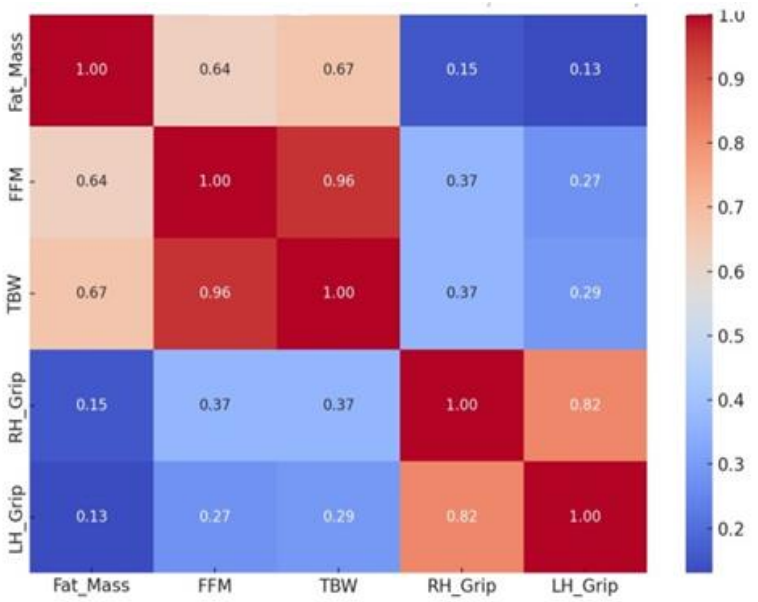

Figure 1. Correlation Matrix among Body Composition Variables and Hand Grip Strength of Indian Soldiers

Median value of normal weight and overweight soldiers could be compared with each other but variability was also perceived within these two assortments. It is interesting to note that a relatively more number of the overweight members showed better performance compared to their peers who were with normal weight category Thus again echoing the need to assess strength based on functionality more than on body size measures. Plots of Fig 1 and Fig 2 show the non-linear non-homogeneous nature of the connection between functional strength and BMI. There can be huge differences between the muscular abilities of soldiers with comparable BMIs based on fat-to-muscle ratio and training history as well as what type of work they have to perform. This finding support that BMI is not an adequate indicator of performance preparedness by people with intensive physical activity such as soldiers.

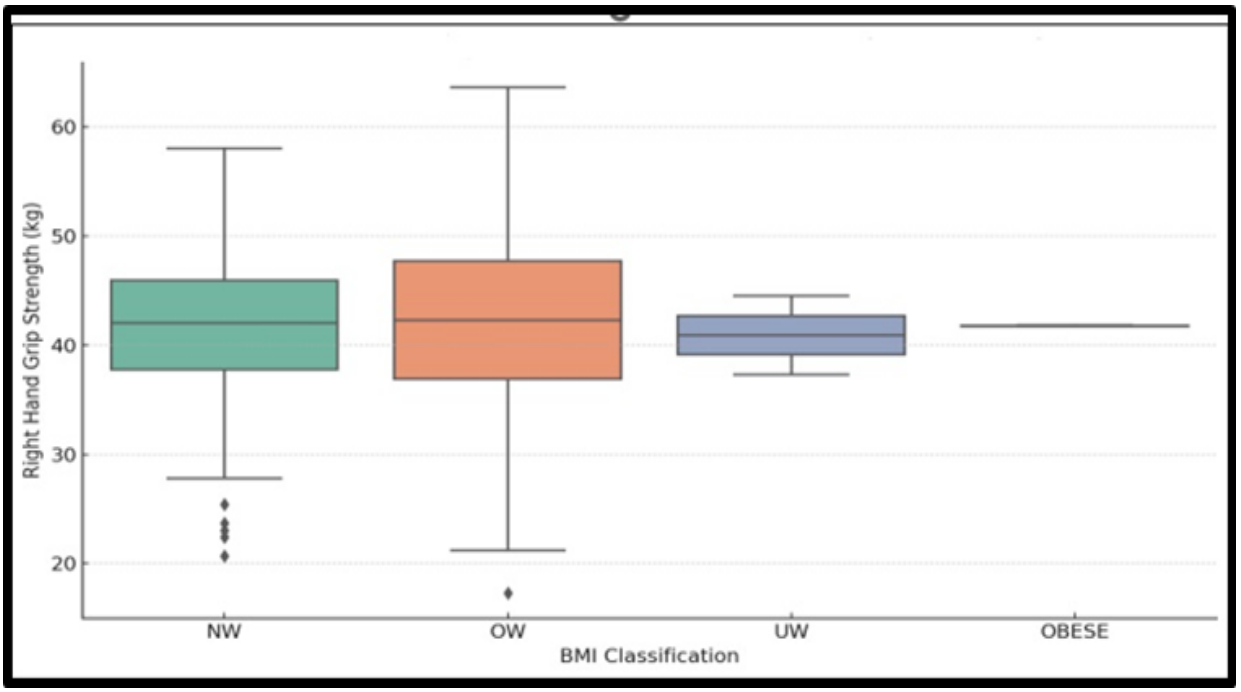

Figure 2. Boxplot Showing Right Hand Grip Strength Across BMI Groups

Discussion

The present study investigated the Body Mass Index (BMI) and hand grip strength among the Indian soldiers working on the BMP II fighting combat vehicles.

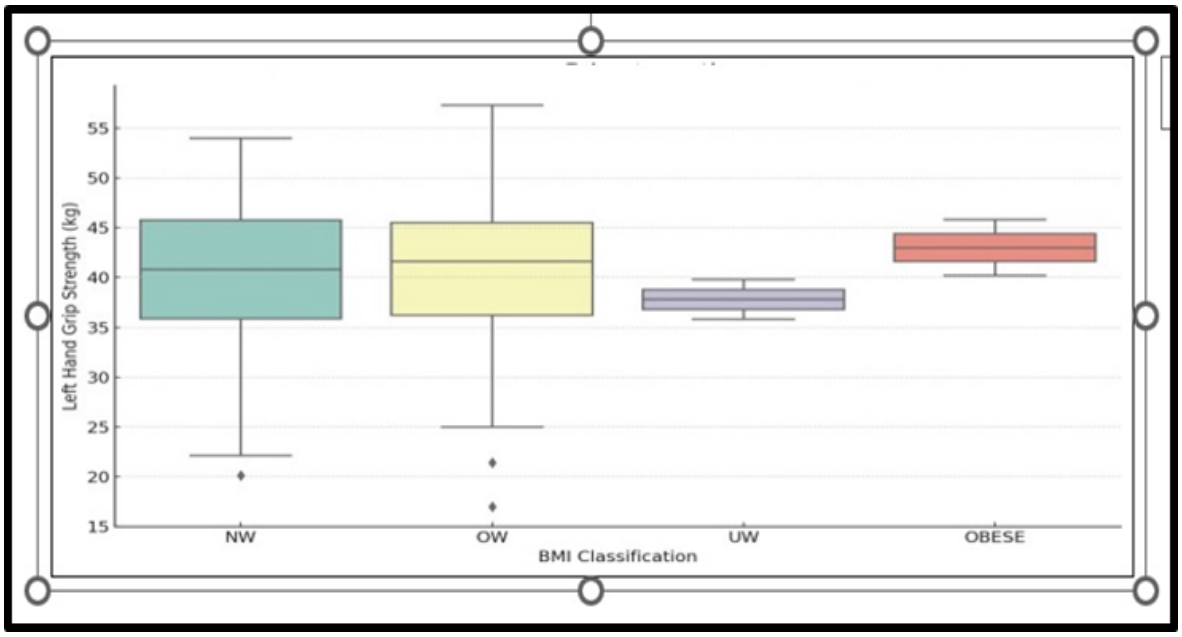

Figure 3. Boxplot Showing Left Hand Grip Strength Across BMI Groups

The results indicate non-linear and a complicated association between BMI and hand grip strength. Despite the fact that a large portion of the soldiers (57.4%) had the normal weight with the Adolphe BMI criterion, there was a large quantity of the overweight and obese soldiers with the scale exceeding 40 percent. Even though this distribution occurred, hand grip strength was not strongly and consistently related to the BMI. In its place, strength was found to be much more reliably associated with Fat-Free Mass (FFM) and Total Body Water (TBW) as these are more representative of the actual muscle content.

The findings indicate that the commonly-used determinant of BMI based on weight and height is not adequate in predicting the upper limb strength in trained persons such as soldiers. BMI will not distinguish between fat and lean mass and therefore people with a lot of muscle mass will be classified overweight or obese. Such an imprecise classification is capable of causing an erroneous evaluation in areas where physical performance is the main determinant.

It was interesting to note that the overweight soldiers tended to have the same or better grip strength compared to those in the normal weight. This observation confirms the possibility that military populations would gain more through the body composition-determined assessments and not through categorizations attributed to have a simple BMI value coinciding to a category.

The results coincide with the findings of the past research, which raised doubt on how BMI can be used as a measure of fitness in active populations. The study by Leong et al. (2015) showed that hand grip strength outlines all-cause mortality better than BMI in different populations worldwide. In the same manner, Choe *et al.* (2021) concluded that muscular strength was associated with lean mass and total body water and not BMI, among the physically active persons. Considering the example of military members, Nindl et al. (2016) stated muscles that are more likely to be exhibited by soldiers and that they were likely to be incorrectly specified as overweight based on BMI alone. These findings are supported in our study, which demonstrates that a considerable portion of soldiers included in the overweight group were characterized by FFM and better grip strength than those of their normal-weight counterparts.

The findings can be of great significance to proper health and fitness evaluation procedures in the Indian army and other related organizations. Nowadays, people apply BMI in regular health screening, hiring, and fitness testing. This study however, recommends that in analyzing the physical preparedness of a soldier, functional tests like grip strength coupled with parameters like body composition provide a more true representation.

In view of the importance of the strength of the upper limbs in the operations of mechanized combat; the handling of equipment, the emergency egresses, and movements in confined spaces, etc., the tests of the muscular functionality are much more applicable, than going by the standard categories of weights.

In addition, personnel with overweight BMI status cannot be obviously ruled out of field duty when their muscular strength and endurance fall within acceptable range of performance. This affirms the use of individual and job-specific fitness standards, as opposed to the population averages.

Limitations of the Study

The study suggests more research in future with a large number of army population of different combat and non-combat positions. Longitudinal designs should be used to determine the changes of BMI, grip strength and body composition with training cycles, deployment, and age.

Conclusion

The study concludes that for Indian soldiers who will drive Military Motor vehicles should have tested with Hand Grip strength for functional strength beside BMI and other body composition variables. During their recruitments.

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Conflicts of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

All the mechanised soldiers included in the study provided written informed consent.

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